Abstract

The present habilitation thesis, entitled "DC-DC Converters – Architectures, Control and Applications," provides a comprehensive analysis of the novel contributions brought to the field of power electronics, specifically in the domain of DC-DC converters.

Starting with an abstract both in Romanian and English, the thesis continues with the summary of research conducted in the PHD studies. It introduces the fundamental principles of DC-DC converters and their classification, covering classical, bidirectional and hybrid topologies architectures. It provides an in-depth review of switching cell structures, emphasizing the role of *L* and *C*-switching configurations in achieving high-efficiency energy conversion. A comparative analysis of existing DC-DC converter topologies is conducted, identifying the limitations and the areas for improvement in terms of efficiency, static conversion ratio and component count. The chapter also presents the motivation for developing novel hybrid converter families, highlighting their potential advantages compared to conventional designs. Additionally, a systematic method for synthesizing new multiphase hybrid converters is introduced, paving the way for these innovative topologies proposed in subsequent chapters.

The main part of the habilitation thesis is presented in Chapter 2. This is an overview of the achievements in scientific, professional and academic field after the PhD thesis was defended in 29.06.2015, at the Faculty of Electronics, Telecommunications and Information Technologies from Politehnica University of Timisoara. It focuses on the scientific research conducted post-PhD, detailing the proposed novelty in DC-DC converter topologies, control methods, and applications,

The focus on scientific research was divided into four key research topics:

1. The development of new families of DC-DC converters, proposing innovative hybrid topologies that improve efficiency and performance, is the first one. Several novel converter structures are introduced, including the Buck-*L*, Boost-*L*, Buck-Boost-*L* and Ćuk-*L* converters, among others, each designed to enhance power conversion for various applications.

Some of these converters employ coupled inductors, interleaved switching, and advanced control techniques to reduce the losses and improve voltage regulation. The strategy used for generating this new converter topologies is substantiated through rigorous mathematical modelling, circuit simulations, and experimental validations.

Comparative analyses with traditional topologies confirm the superiority of these new converters, consisting of higher or lower voltage gain, improved lower voltage or current stresses and higher efficiency. The simulations validated the theoretical considerations developed. Furthermore, the experimental prototypes of the proposed converters all confirmed their practical feasibility, closely matching with the analytical and simulations predictions.

2. The control methods for DC-DC converters are focusing on stability, bifurcation phenomena, and advanced controller design. A stability analysis of a two-phase boost converter is conducted, revealing the key parameters affecting system performance and transient response. Bifurcation studies of discontinuous conduction mode (DCM) operation, highlight nonlinear behaviours and potential instability issues under varying load conditions. Additionally, a

systematic design process for an ideal fourth-order buck-boost converter is presented, optimizing control strategies for improved voltage regulation and efficiency. A refined controller for a fourth-order lossy quadratic buck converter is developed, ensuring robustness against system disturbances. These control strategies provide improved transient response, reduced output voltage ripple, and enhanced system stability, making the proposed converters more reliable for industrial and commercial applications.

3. A major application of the converters proposed is the field of renewable energies, particularly the photovoltaic (PV) and fuel cell systems. The usage of DC-DC converters in PV systems focuses on efficiency improvements and enhanced energy harvesting. A new hybrid inductor-based boost converter has been introduced, specifically designed to optimize step-up voltage conversion for PV applications. Additionally, a SEPIC-based DC-DC converter with coupled inductors is proposed to achieve high step-up capability, while reducing component stress and power losses. These innovative architectures enable better integration of solar energy into modern power grids, increasing the overall system efficiency. The simulations and the experiments conducted validated the superior performance of these converters in terms of voltage gain, reduced ripple, and improved dynamic response. The chapter highlights the critical role of advanced power electronics in maximizing the effectiveness of renewable energy systems.

4. Furthermore, the thesis extends its contributions to the powertrain optimization of battery-fuel cell hybrid vehicles. A novel control strategy for power distribution in battery-fuel cell hybrid vehicles is introduced, ensuring efficient energy management and prolonged battery life. A multiphase DC-DC converter is proposed to enhance powertrain performance, reducing input and output current ripple and improving overall efficiency. Additionally, a dedicated test bench is developed to optimize powertrain configurations, validating the proposed converter designs through experimental analysis. The study also explores bidirectional DC-DC converters for regenerative braking, enabling energy recovery and improved fuel cell efficiency.

The habilitation thesis also highlights the academic and professional contributions of the author, focusing on research dissemination, teaching, and collaboration with industry and academia. It details the author’s merits in publishing in high-impact journal publications: 9 WoS (formerly ISI) papers and 44 conference proceedings papers (32 WoS and 12 BDI papers) showcasing the global recognition of her work in power electronics. The candidate conducted 2 national grants and participated as a member in other 3. The chapter also emphasizes the contributions in mentoring and supervising students, 85 students in graduation bachelor and dissertation thesis (63 bachelor and 22 dissertation), and more than 20 master students guided in the research activity, thus fostering the next generation of researchers in applied electronics. Collaborative research projects are discussed, demonstrating the integration of multidisciplinary expertise in advanced power electronics. Additionally, the author’s role in curriculum development and academic programs improvement is outlined, contributing to enhanced engineering education. Overall, this chapter underscores the author's influence in both scientific innovation and academic leadership.

The last part is devoted to the future academic, professional and research activities, while the work ends with a comprehensive references list.